Analysis of Cross-track Infrared Sounder (CrIS) Prelaunch Test Data

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Abstract: Analyses of Cross-track Infrared Sounder Engineering Development Unit data collected while in bench test and thermal vacuum conditions is presented. Focus is placed on accuracy of the sensor's spectral lineshape and spectral calibration determination.

OCIS codes: (120.3180) Interferometry; (120.0280) Remote sensing

1. Introduction

The Cross-track Infrared Sounder (CrIS) [1] is one of the key sensors being developed for the National Polar-orbiting Operational Environmental Satellite System. Combined with data from the Advanced Technology Microwave Sounder, data from CrIS will be used to retrieve high vertical resolution soundings of the atmospheric state and of the surface and clouds, for improved weather forecasting and other applications. With its expected high radiometric and spectral accuracy and stability, data from CrIS is also expected to be extremely useful for extending the record of accurate infrared observations from space for understanding and monitoring climate. CrIS uses a Michelson interferometer with three spectral bands (nominally 655-1095 cm^{-1}, 1210-1750 cm^{-1}, and 2155-2550 cm^{-1}), each with a 3x3 array of photo-voltaic HgCdTe detectors at the focal plane [2]. As part of the CrIS development effort, ITT Aerospace has built and tested several Engineering Demonstration Units (EDU) in order to mitigate risks for the flight model. The latest EDU is EDU3, which is flight-like in most aspects, and is providing validation of design trades and important information on the expected performance of the flight model [3]. In the summer of 2004, EDU3 underwent a series of bench level tests conducted in a dry N_2 purged environment, including tests used to evaluate the sensor's functionality, thermal stability, radiometric noise, linearity, spatial characteristics, vibration sensitivity, and spectral characteristics. Currently, EDU3 is being integrated into a thermal vacuum test set-up, in which a number of these tests will be repeated under more representative flight temperature and pressure. This paper presents some examples of preliminary results derived from the EDU3 bench level tests. A more detailed presentation of these analyses and those of the thermal vacuum testing, including those regarding spectral characterization using gas cell spectra, will be presented at the meeting.

2. EDU3 Bench Test Radiometric Noise Analysis

Bench level EDU3 test data was collected on 22 May 2004 for the purpose of estimating the radiometric noise. This included "diagnostic mode" interferogram data collection, in which the on-board numerical and decimation process is bypassed, and oversampled interferograms are retained. Ensembles of cold ("ST", 5 C) and heated ("ECT", 30 C) blackbody sources were collected. From the ensemble of radiometrically calibrated ECT views, we extracted estimates of the spectrally uncorrelated noise (e.g. random detector noise) and the spectral correlated noise (e.g. due to interferometer wavefront misalignments). For this data collection, an on-board circuit to account for optical path difference sample position errors was turned on.

In Figure 1 are shown these noise estimates for each of the three spectral bands for the center FOV (FOV number 5) as compared to the flight spec values. The noise performance of EDU3 is very good and the flight spec is met or exceeded for nearly all wavelengths. Exceptions are isolated spectral regions where CO_2 absorption is high (in the bench test configuration), and at the shortwave end of the LW band, where the transmission of certain optical elements is high for the warm bench test conditions. Also, for the flight model, improved detector optics for the MW and SW bands are expected to improve upon these values. Compared to noise estimates of the Atmospheric Infrared Sounder (AIRS) on the EOS Aqua platform, these EDU3 total noise estimates are similar in the SW regions where the noise of both sensors is photon limited and signal dependent. Throughout the 15μm temperature sounding region, the EDU3 noise estimate is roughly a factor of 4 lower than that of AIRS.

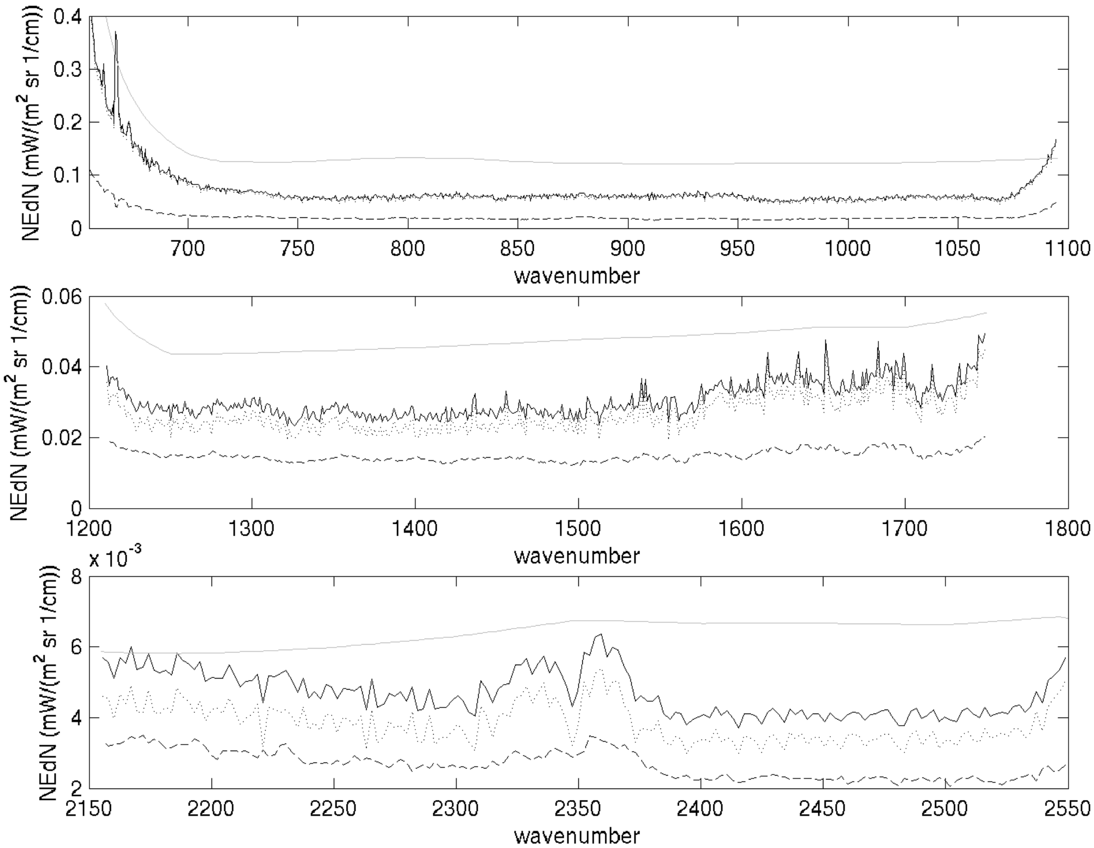

Fig. 1. Radiometric noise estimates for the EDU3 derived from calibrated external blackbody calibration target views collected on 22 May 2004 while in bench test configuration. The gray curve is the CrIS flight model spec value, the solid black curve is the EDU3 total noise estimate, the dashed black curve is the spectrally correlated (e.g. interferometric) noise estimate, and the dotted black curve is the spectrally uncorrelated (e.g. random) noise estimate.

3. EDU3 Bench Test Spectral Lineshape Analysis

To confirm the expected Instrument LineShape (ILS) functions of EDU3 as predicted by the maximum optical path delay of the interferometer and the interferometer/detector array geometry, two basic types of spectral characterization tests were performed in the bench test configuration. This included gas cell transmission tests, in which a cell is filled with an absorbing gas, and the transmission is derived by combinations of hot and cold, full and empty gas cell views. The derived transmission spectra can then be compared with theoretical calculations to evaluate the spectral calibration and ILS. Also, for the longwave band, for which a suitable infrared laser was available, views of the laser source emission is used to fill the sensor field of view, and the spectral lineshape can be determined from the response to the monochromatic input. This laser data has also been shown to be very useful for characterizing the sensor linearity.

ILS laser data was collected on 02 June 2004 using a 10 mm CO_2 laser to fill an integrating sphere, which the EDU3 viewed. Ensembles of hot and cold blackbody views and views of the integrating sphere (IS) with the laser source open and blocked were collected, and mean spectra computed for each ensemble. Subtracting the blocked IS view from the open IS view, and multiplying by a responsivity derived from the blackbody views yields the measured ILS function. This was done for all fields of view and a small adjustment in the position of the detector array with respect to the interferometer axis was determined. Comparisons of the EDU3 ILS functions for the center FOV (FOV5), an edge FOV (FOV4) and a corner FOV (FOV1) to what is expected based on the sensor design [4] is shown in Figure 2. A detailed analysis of the results shows that the measured ILS agree very well with expected, with centroid positions agreeing to several parts per million and full widths agreeing to 0.5 percent or better for all fields of view.

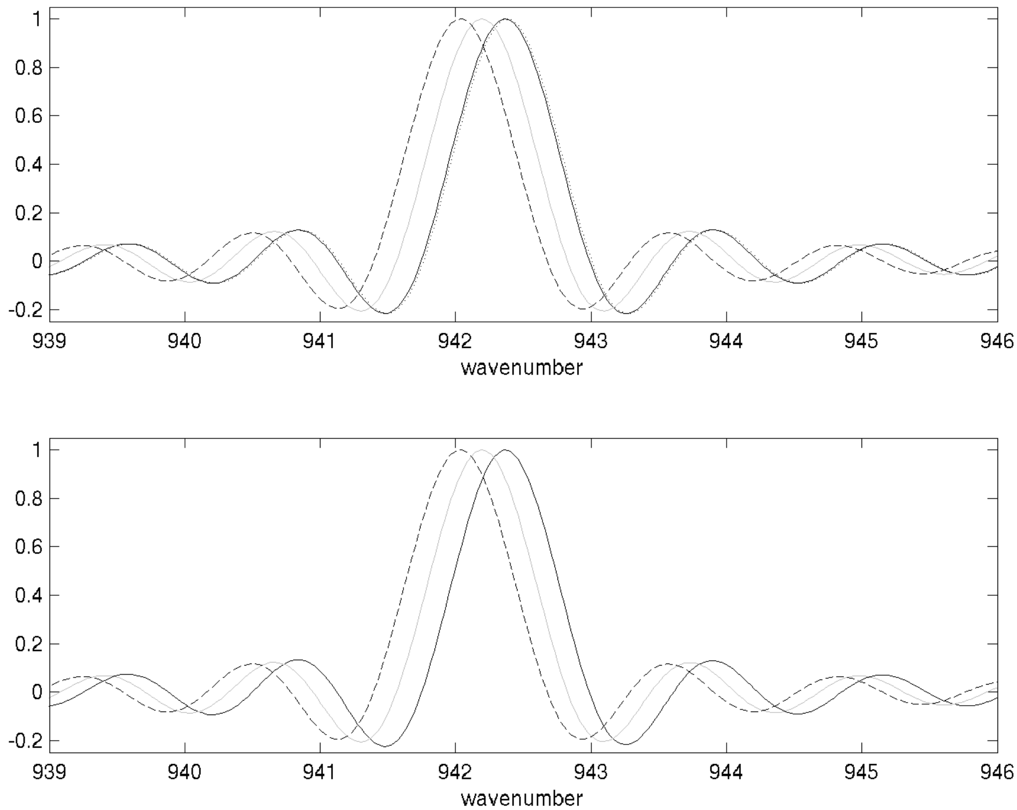

Fig. 2. Comparisons of expected (top panel) and measured (bottom panel) instrument lineshape (ILS) function for EDU3, for the center FOV5 (solid black), an edge FOV4 (solid gray), and a corner FOV1 (dashed black). Also shown in the top panel (dotted black) is a pure sinc function of the input laser wavelength and the CrIS maximum optical path difference.

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